

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 6

EXPERIMENTS WITH CELLS



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Experiment Lesson 6

OBJECT

The object of the experiments in this lesson is to confirm the following statements made in Theory Lesson 5:

1. Carbon-zinc dry cells are connected together in series to form batteries of various voltages.
2. When cells are connected in *series aiding*, the voltage of each cell adds to the next voltage.
3. It is possible to connect cells so that they don't aid.
4. Electrical pressure or emf exists between some common substances when they are placed in an alkaline, acid, or salt solution.
5. The emf produced by chemical action between two metals or other substances placed in an acid, alkaline, or salt solution of proper strength is determined by the metals used.
6. The emf produced by chemical action is not affected by the size of the cell, the amount of metal, and the spacing of the metals.

PREPARATION

In order to prepare for these experiments, read and study Theory Lesson 5. When you are sure that you understand the information given in Theory Lesson 5, proceed with the experiments given in this lesson. If you have trouble understanding some point in an experiment, stop what you are doing and read Theory Lesson 5 again until the point is cleared up and you find the answer to your problem.

INFORMATION

The experiments in the first part of this lesson are best performed where the lighting in the room is not too bright to keep you from observing the brightness level of a small flashlight bulb. Bright lights in the room should be turned off; medium to low lighting should be used. The equipment needed to perform this experiment probably can be found in your own home, making it unnecessary to buy anything.

PART ONE

OBJECT

The object of the first part of this lesson is to:

1. Test the total potential across a battery made up of 1.5-volt dry cells that are connected in *series aiding*.
2. Test the total potential across a battery made up of 1.5-volt dry cells that are connected in *series opposing*.
3. Test the total potential across a battery made up of 1.5-volt dry cells that are connected as a combination of both *series aiding* and *series opposing*.
4. Test the potential across a battery made up of dry cells that are connected in parallel.

In each of the following experiments, you will use your sense of sight and sense of taste to observe the strength of the total battery voltage. You will use your sense of sight by observing the brightness of a small, low-voltage lamp; you will also judge the potential strength by means of taste sensa-

tions. For example, if two conductors that carry a low d-c potential are placed on the tongue, the tongue will receive a certain taste sensation. If the voltage is reduced, the taste sensation will not be as strong.

Caution: Never place conductors or wires in the mouth unless you are sure that the potential is obtained from battery cells and does not exceed 3 volts.

In future lessons, you will use a meter for testing and will have no further use for this method.

EQUIPMENT NEEDED

- One 6-volt pilot-light bulb
- One pilot light socket
- Three 1.5-volt dry cells
- One 6-foot length of pushback wire
- Soldering iron
- Solder
- Cutting pliers
- Fine sandpaper
- Clean cloth

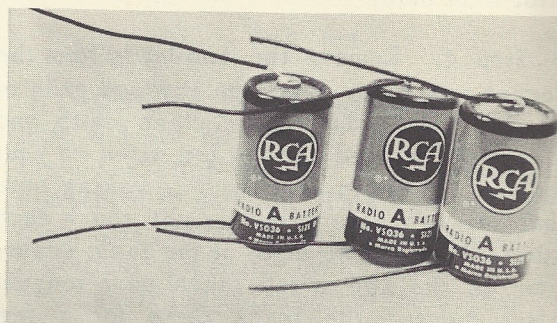
PREPARATION OF PARTS

In order that different methods of connecting the individual cells may be used, it will be necessary to solder separate wires to the positive and negative terminals of the three 1.5-volt dry cells. Connect the wires as follows:

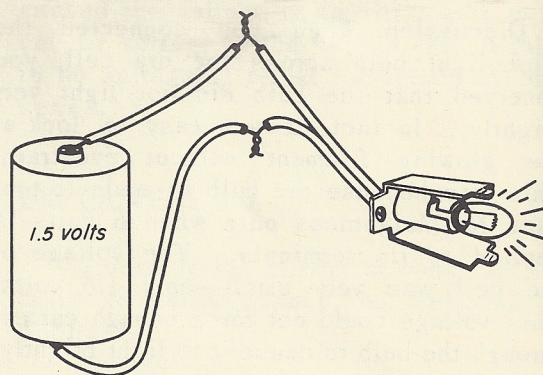
1. Using the cutting pliers, cut six 4-inch lengths of pushback wire.
2. Push back the insulation for 1/2 inch from each end of each of the 6 leads.
3. Lightly clean the top surface of the brass positive terminal of each of the 1.5-volt cells with the sandpaper.
4. Solder a lead to the brass positive terminal of each cell, as shown in Fig. 6-1a.
5. Clean a small spot on the zinc bottom of each cell.
6. Solder a lead to the clean spot on the



(a)



(b)



Pilot light connected to 1.5 v cell

(c)

Fig. 6-1

bottom of the zinc casing of each cell. Your finished work should look like Fig. 6-1b.

Caution: Do not allow the two exposed leads of a cell to touch each other. If you do, the cell will become short-circuited and discharge in a short time.

EXPERIMENT 6-1

To test one dry cell using pilot-light and socket.

Procedure.

Step 1. Insert the 6-volt pilot-light bulb in its socket.

Step 2. Holding one lead of one of the dry cells in each hand, carefully contact the two terminals of the pilot-light socket with the bared ends of the two leads, as shown in Fig. 6-1c.

Step 3. Observe the brightness of the pilot-light bulb.

Step 4. Remove the two leads from the socket terminals. Wipe the exposed ends of the two leads with a clean cloth and place the exposed ends of the wires on your tongue, as shown in Fig. 6-2, making sure that the two bare wires do not touch each other. Note the strength of the taste sensation as the two wires touch your tongue. After holding the leads there for a few seconds, remove them from your mouth.

Discussion. When you connected the pilot light bulb across the dry cell, you observed that the bulb did not light very brightly. In fact, it was easy to look at the glowing filament without eyestrain. This was because the bulb is made to produce full brightness only when 6 volts is applied to its terminals. The voltage of the cell was very small—only 1.5 volts. This voltage could not force enough current through the bulb to cause it to light brightly.

You noticed, too, that the taste sensation received by your tongue was not too

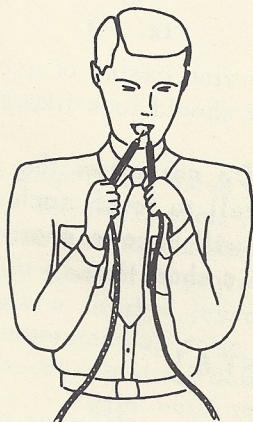


Fig. 6-2

strong. The 1.5 volts of the cell was not enough to produce much sensation.

EXPERIMENT 6-2

To observe, by sight and taste, the effects of increasing the voltage.

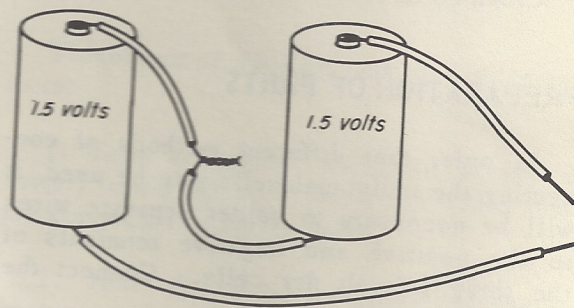
Procedure.

Step 1. To obtain a total potential of 3-volts, connect two of the 1.5-volt dry cells in *series aiding*, as shown in Fig. 6-3a.

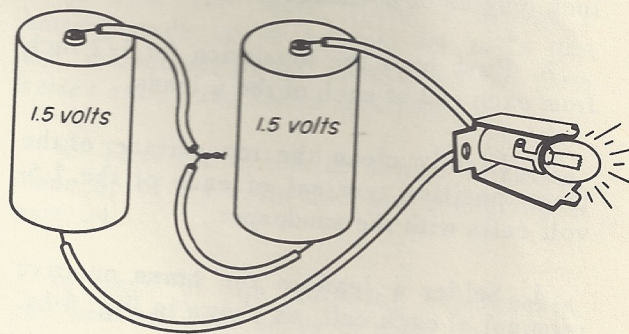
Step 2. Connect the two series-connected cells to the pilot-light socket, as shown in Fig. 6-3b.

Step 3. Observe the brightness of the bulb. Notice how much brighter it glows with a potential of 3 volts than when a potential of only 1.5 volts was used.

Step 4. Remove the two leads from the



two cells connected series aiding
(a)



two cells connected in series aiding across
the pilot light

(b)

Fig. 6-3

socket and wipe their ends clean. Place the two leads on your tongue. The taste will seem stronger and more salty than the taste you experienced when a potential of 1.5 volts was used. Remove the two wires from the tongue.

Discussion. When the bulb was placed across the two series-aiding cells, it was easy to see that the electrical potential or voltage had increased over that obtained by using only one dry cell. The filament of the bulb glowed brightly, showing that the doubled electrical pressure forced more current through the resistance of the filament. Stated more simply, the increased voltage simply caused a greater electron movement through the filament wire. The filament wire, being a poor conductor of current, became hot and glowed even when only 1.5 volts was used; it became *hotter* and glowed brighter when 3 volts was used. The increased heat and light were due to the increased quantity of electrons forced through the thin, high-resistance filament wire.

The tongue, as we now realize, is sensitive to differences in electrical current flow. The increased voltage, due to two series-aiding cells, produced more current flow through the moist tongue; the taste sensation informed you that you could actually taste the greater force of the two cells.

EXPERIMENT 6-3

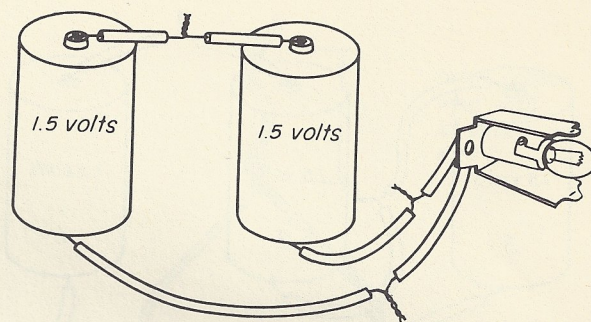
To connect two cells in series opposing and observe the effects by sight and taste.

Procedure.

Step 1. Connect two 1.5-volt cells in *series opposing*, as shown in Fig. 6-4.

Step 2. Connect the terminals of this series to the pilot-light socket and observe the filament of the bulb. Does it glow?

Step 3. Remove the leads from the socket and test the potential of the series with your tongue, as before. Is there any taste sensation? Does it have the sensation of one or two cells?



two cells connected in series opposing across pilot light, light does not light

Fig. 6-4

Discussion. You probably found that the bulb did not glow at all and that the only taste sensation was that of two plain wires connected to nothing. This was because an electrical tug-of-war was taking place. The electrical pressure (voltage) of the first cell equaled the pressure of the second cell, and, because the pressures were in opposite directions, they balanced each other. This caused the voltage of the first cell to cancel the voltage of the second cell, resulting in no voltage at all at the terminals of the series.

EXPERIMENT 6-4

To observe the effects of connecting two cells so as to *oppose* the potential of a third cell.

Procedure.

Step 1. Connect the three cells as shown in Fig. 6-5, with cells 2 and 3 aiding and opposing cell 1. Connect the terminals of this series to the terminals of the pilot-light socket.

Step 2. Observe the glow of the heated filament. Make a mental comparison between the brightness obtained now and when a single cell was used.

Step 3. Remove the leads from the socket and test the series with your tongue. Is the taste sensation greater than that of a 3-volt battery, or is it more like that of a single cell?

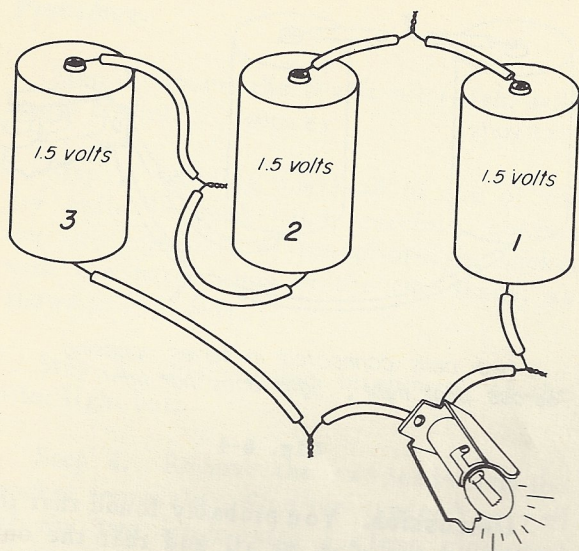


Fig. 6-5

Discussion. In this experiment, another electrical tug-of-war was taking place. Cell 1 and cell 2 balanced each other out by acting as though they were pulling on opposite ends of a rope; in this manner, they *opposed* each other. Cell 3, not having another cell to oppose, was free to exert its 1.5 volts of electrical pressure and force current to flow through the circuit. The circuit behaved as though cells 1 and 2 were not there, and cell 3 was acting alone. The potential of cell 1 cancelled the potential of cell 2, leaving a potential of cell 3 to do the work.

EXPERIMENT 6-5

To connect two cells in parallel and observe the results by sight and taste.

Procedure.

Step 1. Connect two cells in parallel, as shown in Fig. 6-6, making sure that the polarities (+ and -) are as shown.

Step 2. Connect the cells to the pilot-light socket and observe the glow. Is it like the glow that you observed when one cell or when two cells were connected in series?

Step 3. Remove the leads from the socket and test the voltage with your tongue. Does it taste like 1.5 volts or like 3 volts?

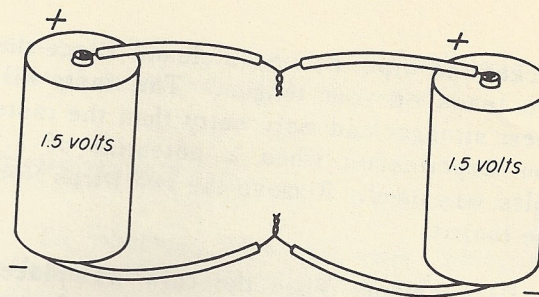


Fig. 6-6

Discussion. In this experiment, you observed that the two parallel-connected cells had the same electrical pressure as a single 1.5-volt cell. In other words, if one cell had been disconnected completely and removed from the circuit, leaving only one cell, the lamp would have had the same brilliance and the taste sensation would have been the same. Why bother connecting two cells in parallel, when one cell delivers the same voltage? The reason is simply this: Each cell in a parallel-connected circuit shares the current flowing through the load; this means that they last longer and will not discharge as quickly as a single cell.

In all of the preceding experiments, you used dry cells, which have a potential of 1.5 volts d.c. You learned in Theory Lesson 5 that the positive electrode of such a cell is made of carbon, the negative electrode is made of zinc, and the electrolyte is ammonium chloride in paste form.

In the experiments that follow, you will make your own battery cells by using two dissimilar metals in a home-made electrolyte.

PART TWO

OBJECT

The object of this part of the lesson is to:

1. Construct three home-made cells.
2. Use the sense of taste to determine if an emf is present.
3. Attempt to force current through the

high internal resistance of the cells so as to light a pilot-light bulb.

4. Determine if a potential can be developed across two electrodes made of the same metals.

5. See if the potentials of a cell can be affected by changing the make-up of a cell, by changing the quantity of electrolyte, or by changing the size and spacing of the metals used for the electrodes.

PREPARATION

Review Theory Lesson 5 so that you will be prepared to perform the following experiments. Since you are going to assemble three cells, you should become familiar with the part of Theory Lesson 5 that explains the action of different metals in an electrolyte solution.

These experiments are best performed on a kitchen table or worktable located where accidental spilling of liquid will not do much damage. However, since all of the materials used are common substances found in your home, no special precautions need be taken.

EQUIPMENT NEEDED

- Three water tumblers
- Eight ounces of cider vinegar
- Three feet of stranded iron picture-hanging wire
- Three feet of bare copper wire (not tinned)
- Pilot-light bulb and socket (used in Part One)
- Cutting pliers
- Six inches of adhesive tape or cellophane tape

ASSEMBLY OF CELLS

Three cells will be assembled, each using an acid (vinegar) as the electrolyte. The electrodes will consist of copper (+) and iron (-). Assemble the cells in the following steps:

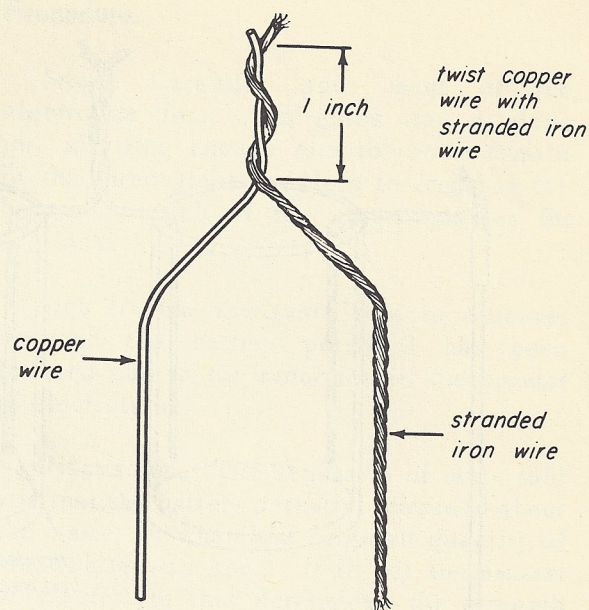


Fig. 6-7

Step 1. Cut three 6-inch lengths of copper wire and three 6-inch lengths of iron wire.

Step 2. Make up two pairs of joined electrodes by tightly twisting together a copper wire with an iron wire for a distance of one inch, as shown in Fig. 6-7.

Step 3. Place the two pairs of joined electrodes and the remaining single copper and iron electrodes in the glass tumblers in the arrangement shown in Fig. 6-8. Arrange the electrodes and the spacing between the glass tumblers so that each electrode is about $\frac{1}{4}$ inch from the bottom of the glass.

Step 4. Fasten each electrode to the top edge of the glass, using six 1-inch strips of cellophane or adhesive tape, one strip for each electrode.

Step 5. Carefully pour an equal quantity of cider vinegar into each glass, allowing each glass to become about one-third full.

Step 6. Wrap the bare end of the single copper-wire electrode around one of the 3-foot test leads, by twisting them together, as shown in Fig. 6-8. In the same way, connect the other 3-foot test lead to the single iron-wire electrode.

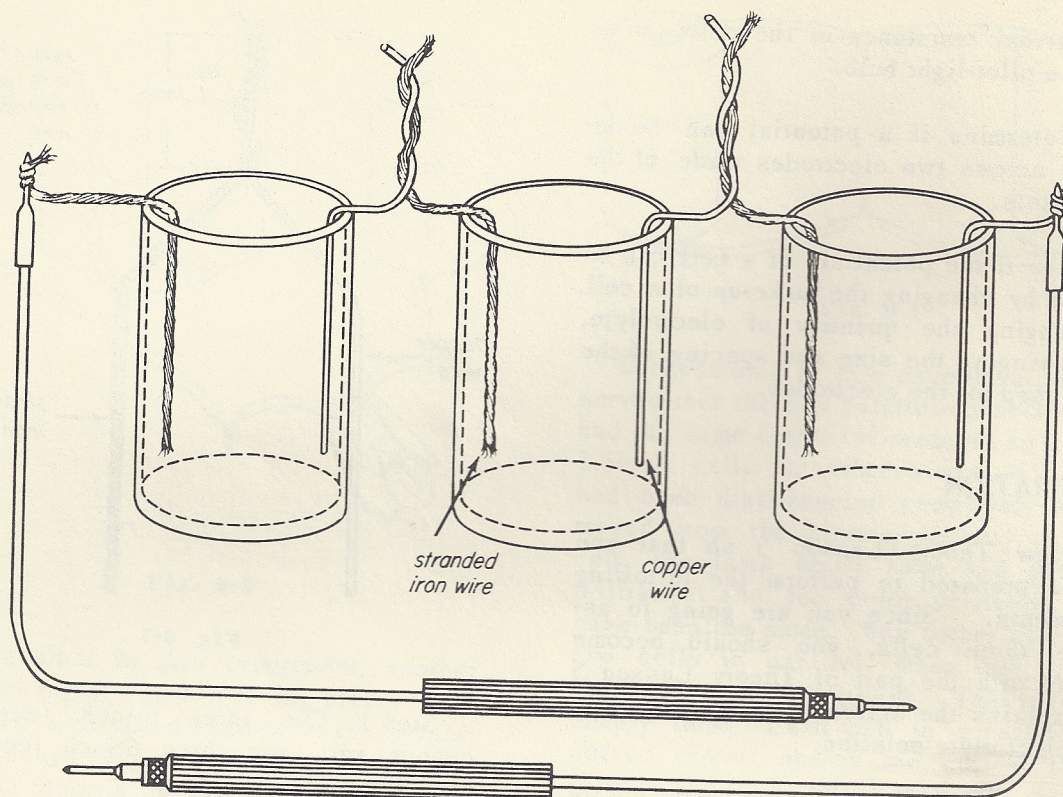


Fig. 6-8

EXPERIMENT 6-6

To test the potential of three home-made cells.

Procedure.

Step 1. Wipe the free ends of the two 3-foot leads with a clean cloth and place the exposed ends of the wires on your tongue as in the other experiments.

Step 2. Note the strength of the taste sensation and compare it with the taste sensation of the series-connected dry cells. Try to guess the value of emf produced in the experiments in Part One of this Lesson. Remove the test leads from your mouth.

Step 3. Connect the 3-foot leads to the two terminals of the pilot-light socket. Do not be surprised if the bulb does not light or even glow faintly. This will be explained in the discussion that follows.

Discussion. Your taste sensation told you, in Step 2, that a voltage was pres-

ent. This proved that electrical pressure existed when unlike metals were placed in an acid. Since the three copper-iron cells were connected in series-aiding, the total emf across the ends of the 3-foot test leads was three times the value of the voltage of one of the copper-iron cells. The total potential across the three home-made cells is equal to about the same voltage as a single 1.5-volt dry cell. In other words, the potential of each of your home-made copper-iron cells is equal to about 0.5 volt under load. Your tongue was the load. If the total emf of the three cells is 1.5 volts, why did the pilot-light bulb fail to glow when it was placed across the three series-connected cells in Step 3? The answer is that the internal resistance of each of the home-made cells is very high and does not pass enough current to heat the filament. The resistance of the filament is very low compared with the total internal resistance of the battery. When the battery resistance and the filament resistance are combined, the voltage divides; practically *all* of the battery potential is across its own internal resistance, and very little voltage remains

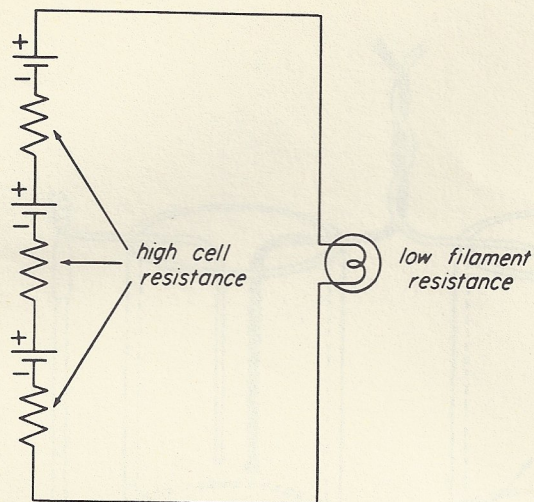


Fig. 6-9

to operate the bulb. (See Fig. 6-9.) Although a voltage-dividing action took place when the high resistance circuit of your tongue was in series with the high resistance of the battery, both *loads* showed high resistance. Therefore, part of the battery voltage remained across the wires resting on your tongue, allowing enough current to flow to arouse the sensitive sense of taste.

You might ask why the emf produced by each of the home-made copper-iron cells is only about 0.5 volt? The Electrochemical Series Table in Theory Lesson 5 shows that the emf should be about 0.78 volt. The answer is that the vinegar used as the electrolyte is a very weak form of acetic acid. If a strong solution had been used, a greater emf would have been produced. In addition, the capacity of each cell was very small because the area of the electrodes exposed to the electrolyte was very small. So, when a load (the bulb or tongue) was applied to the terminals, the current drawn exceeded the capacity of the cells. Therefore, the positive electrode became polarized, and the internal resistance increased. As a result, very little power was delivered to the load.

EXPERIMENT 6-7

To reduce the quantity of electrolyte in order to observe the effect on the emf produced.

Procedure.

Step 1. Carefully pour most of the electrolyte from each glass into a glass jar, allowing enough electrolyte to remain in the three glass tumblers to immerse the bottom of each of the six electrodes for 1/2 inch.

Step 2. Use the taste test to discover whether the battery potential has been lowered due to the reduction in the amount of electrolyte.

Discussion. The sensation of taste told you that the battery potential remained about the same as when the original quantity of electrolyte was used. It is not the *amount* of electrolyte that determines the strength of the generated emf, but the strength or *type* of electrolyte used.

EXPERIMENT 6-8

To find what effect distance between the copper and iron electrodes has on the voltage of the cells.

Procedure.

Step 1. Repeat the taste test of Experiment 6-7, Step 2, and try to remember the amount of sensation your tongue receives.

Step 2. Bend all of the copper- and iron-electrode wires in the three glass tumblers so that there is only about 1/4 inch between each pair. Make sure that the electrodes do not touch each other. This arrangement is shown in Fig. 6-10.

Step 3. Determine again, by means of the taste test, whether the battery potential has changed due to the difference in spacing between the electrodes.

Discussion. Your sense of taste told you that the potential strength of the cells remained the same, even though the spacing between the electrodes was changed. Of course, if you had carelessly allowed an iron electrode and a copper electrode in one of the cells to touch, the cell would have been shorted out of the circuit, and

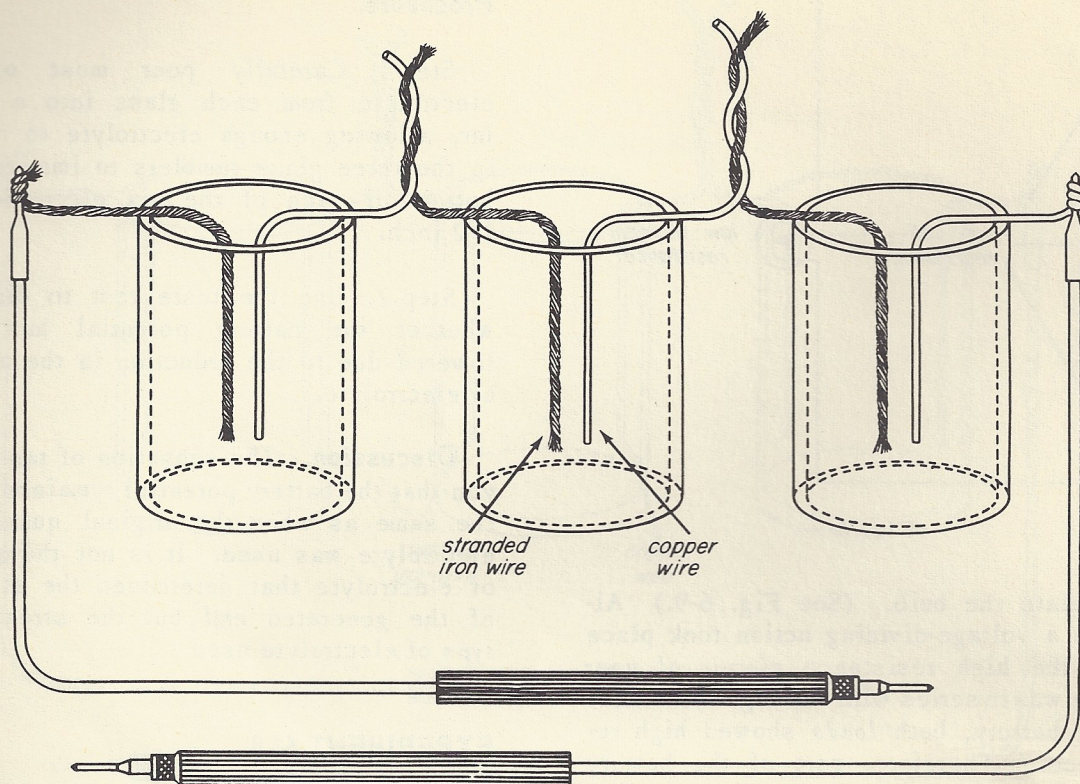


Fig. 6-10

the potential strength of the battery would have been decreased to two-thirds of its original total value.

EXPERIMENT 6-9

To learn what effect the use of electrodes made of the same metal has on the emf produced.

Procedure.

Step 1. Remove the three copper-wire electrodes from the three cells and replace them with iron-wire electrodes. The three

cells should now have iron-wire electrodes only.

Step 2. Repeat the taste test and try to detect any signs of voltage.

Discussion. Your taste sensations informed you that no potential was present. This proved that, in order to produce an emf, it is necessary to place *different* metals in an electrolyte solution. The iron wire used for one of the electrodes is just as negative with respect to hydrogen as the other electrode made of iron wire. Since *both* iron-wire electrodes are equally negative, zero potential exists between them.